This document is intended as a guideline for success in IB internal assessment. Three criteria are assessed based on lab work submitted in a report or other format. They are: DESIGN, DATA COLLECTION AND PROCESSING, and CONCLUSION AND EVALUATION. Each criterion is divided into three aspects which are individually evaluated.

Data collection and processing (DCP)

The IBO rubric for DCP is shown below:

Data collection and processing

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Recording raw data	Processing raw data	Presenting processed data
Complete/2	Records appropriate quantitative and associated qualitative raw data, including units and uncertainties where relevant.	Processes the quantitative raw data correctly.	Presents processed data appropriately and, where relevant, includes errors and uncertainties.
Partial/1	Records appropriate quantitative and associated qualitative raw data, but with some mistakes or omissions.	Processes quantitative raw data, but with some mistakes and/or omissions.	Presents processed data appropriately, but with some mistakes and/or omissions.
Not at all/0	Does not record any appropriate quantitative raw data **or** raw data is incomprehensible.	No processing of quantitative raw data is carried out **or** major mistakes are made in processing.	Presents processed data inappropriately **or** incomprehensibly.

Aspect 1 – Recording raw data

This aspect evaluates the presentation of observations and data collected during the course of the experiment. Such data is called raw data and will consist of the measurements you made during the lab. Raw data must be presented neatly and in a format that is easy to understand. This will almost always require a table.

Data Table Reminders

- Use a standard row/column format
- Draw a box around the table and use lines where appropriate to separate rows/columns of data
- It is common practice to write the independent variable data in a column to the left of the dependent variable data.
- Table headings must include units of measurement and any applicable uncertainties
- Titles for tables are very important. Titles must be meaningful and contain a written description of data presented.
- Do not overlap a table on two pages. Keep all data on one page!

Example

Table 1: Change in volume of a fixed mass of air with increasing temperature.

Absolute Temperature / ±1 K	***Volume of Air / ±0.3 cm³***
274	*10.2*
301	*11.2*
316	*11.8*
342	*12.7*
369	*13.7*

Notes

- Units of measurement are critical. The slash "/" is used to denote units of measurement. Alternative presentation uses parentheses.
- The title is **descriptive** and includes "Table 1". Numbering tables makes discussion of data easier because you can easily refer to a specific table.
- All measurements are made and recorded to the **same precision** (the same number of decimal places) and the uncertainty is an absolute value (not a percentage) and given to **one** significant figure.
- If uncertainty is negligible, ignored or requires other explanation, present justification as a footnote under the table.
- Data included in tables can be quite cumbersome to present if there is a great deal of raw data or if multiple measurements are made. Give this some thought and make the appropriate effort to present the data clearly.

Qualitative observations are critical to fulfilling this criterion aspect. These observations can be listed, presented as an annotated diagram or incorporated into the raw data table.

Summary of IB Evaluation Criterion: Data Collection and Processing

THIS IS YOUR CHECKLIST!

Aspect 1 –Recording raw data

This aspect evaluates the recorded quantitative and qualitative observations made during the experiment.

- Ensure relevant **qualitative observations** are included.
- All quantitative measurements **must include** units and a reasonable uncertainty.
- Pay attention to significant digits in both the data and uncertainties.

Aspects 2 and 3- Processing raw data and Presenting

Raw data is processed in the analysis section and the results presented (**Note: it is quite common for both raw and processed data to be presented together**). Data processing includes any calculated values obtained from raw data and averages. Processing also includes plotting raw data (and/or calculated values) on a suitable graph, converting sketches to formal diagrams etc. Plotting raw data without a trend line (and slope calculation) DOES NOT constitute processing.

The most important consideration when processing data is to perform calculations correctly. For assessment purposes, it is essential that an example for each calculation is presented clearly to show the method or rationale utilized.

Presenting processed data 1 - TABLES:

- it is essential to **distinguish raw data** from processed data in tables. If you wish to combine data into one table, one way to indicate columns of processed data is to use a double line.
- **sample calculations** are presented after a table to clearly show how the processed table values were obtained. YOU DO NOT NEED TO SHOW A CALCULATION FOR EACH LINE OF DATA.
- uncertainties should be determined wherever possible (calculated or estimated) for ALL processed data **including best fit lines on graphs**. Include an example that shows how the uncertainty was calculated or determined.
- if an uncertainty is not significant – **this must be mentioned and explained**

Example

Table 2: The effect of increasing pressure on the volume of a fixed quantity of hydrogen at a constant temperature (293 K).

Pressure /±0.1 kPa	***Gas Volume / ±1 mL***	***R (gas constant) /J•mol^{-1}•K^{-1}***
101.3	*456*	*8.32 ±0.08*
145.6	*317*	*8.31 ±0.08*
198.2	*233*	*8.32 ±0.09*
246.9	*185*	*8.2 ±0.1*
302.0	*152*	*8.3 ±0.1*
353.4	*131*	*8.3 ±0.1*
	Mean Value	*8.3 ±0.1*

Sample calculation of R and uncertainty (ΔR) using first row of data.

Note that volume data is converted to dm^3, T = 293 ± 1K, n = 0.01894 ± 0.00005 mol

Calculate R

$$R = \frac{PV}{nT}$$

$$R = \frac{101.3(0.456)}{0.01894(293)}$$

$$R = 8.32$$

Uncertainty in R

$$\Delta R = R \times \left(\frac{\Delta P}{P} + \frac{\Delta V}{V} + \frac{\Delta T}{T} = \frac{\Delta n}{n} \right)$$

$$\Delta R = 8.32 \times \left(\frac{0.1}{101.3} + \frac{1}{456} + \frac{1}{293} + \frac{0.00005}{0.01894} \right)$$

$$\Delta R = \pm 0.08 \text{ (one S.F.)}$$

Uncertainty in mean

$$\Delta \bar{R} = \frac{\max - \min}{2}$$

$$\Delta \bar{R} = \frac{8.4 - 8.2}{2}$$

$$\Delta \bar{R} = \pm 0.1 \text{ (one S.F.)}$$

Error in Experimental Mean

Accepted value for R = 8.314510 J•mol^{-1}•K^{-1} (Serway, 2002)

To determine percent error in experimental mean:

$$\% \text{ error } = \frac{|8.314510 - 8.3|}{8.314510} \times 100\%$$

$$\% \text{ error } = 0.12\%$$

Note the following:

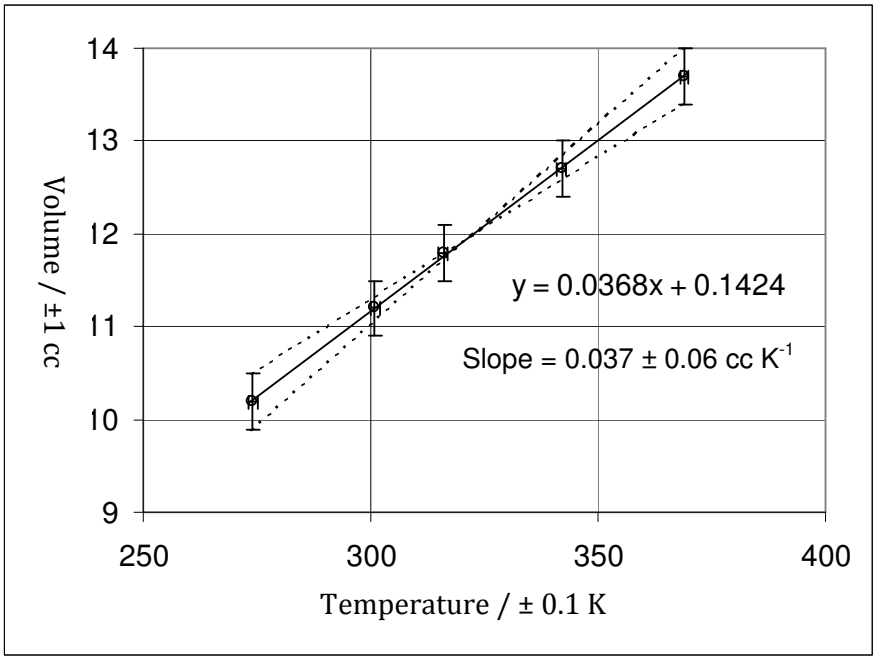
- the title describes the conditions of the experiment including the fixed conditions (quantity of gas and temperature are controlled variables)
- a double line separates measured values from processed values
- a sample calculation for R is shown below the table (including uncertainty)
- the uncertainty for each calculated value of R varies so it is included directly in the table (instead of in the heading)
- showing the calculation of mean with uncertainty is not usually required i.e. it is a standard calculation regardless of the nature of the data
- the percent error in the mean (deviation from accepted value) calculation is performed here. This comparison will be required in the Conclusions and Evaluation section of the lab report.
- the literature value is referenced

Presenting Processed Data 2 – Graphs:

- only use Excel (or other) if you know what you are doing. There is nothing wrong with a hand plotted graph on proper paper.
- graphs should be at least one third of a page in size
- paste graphs into the body of the report so that a logical sequence of information is presented

Example (from Table 1 data)

Graph 1: The relationship of the volume of air in a syringe subjected to an increase in absolute temperature



This graph shows the linear relationship between the independent and dependent variables in this investigation. If a trend is not linear, attempts must be made to manipulate variables mathematically (transformed) to obtain a straight line relationship. The transformed graph would be presented after the original graph and would probably be the main focus of discussion.

Notice how the x-axis uncertainty bars appear on the graph. If the uncertainty is very small relative to the scale on the axis, the uncertainty bars can be too small to see. This should be noted on the graph (for example, include in the title that *due to the relatively small uncertainty, the uncertainty bars for Temperature are too small to be included*).

Maximum and minimum best fit lines are included to determine the uncertainty in the slope of the plotted best fit line. This is essential!

Don't forget: Your graph must include

- descriptive title
- labeled axis with units
- appropriate scale
- properly plotted points with uncertainty bars (or an explanation if not included)
- line of best fit (linear or curve)
- the equation of line – if linear (use points on the best fit line to calculate)
- legend or key (if more than one series of data)

Students often fail to realize the significance of data processing and tend to focus more on presenting processed data. The analysis of data has three primary purposes:

1. Determining if there is a trend relating the two plotted variables and expressing the trend mathematically (i.e. $y = mx + b$ or $y = kx^2$ etc.). This requires graph analysis.
2. Comparing a calculated value to a known or accepted value. This may mean comparing a slope, extrapolated or average value to a quantity obtained from the literature (for example comparing an experimental value of "g" to 9.81 ms^{-2}) or an expected result (for example the slope of a graph might be expected to be zero).
3. Looking at data values (plotted or otherwise) for evidence of random or systematic error.

For data analysis to mean something, you must understand what you are looking for.

Summary of IB Evaluation Criterion: Data Collection and Processing

THIS IS YOUR CHECKLIST!

Aspect 2 –Processing raw data

This aspect evaluates the manipulation of raw data values.

- Double check calculations are correct.
- A trend line must be included for any plotted data.

Aspect 3 –Presenting processed data

This aspect evaluates the presentation of processed data including the propagation of uncertainty, and utilizing a suitable presentation format that effectively communicates the processing.

- Include a sample calculation for each manipulation performed. Present clearly so the reader can understand where substituted values come from and the nature of the calculation.
- All graphs and tables need to have clear, unambiguous headings.
- All graphs require axis labels, units, and appropriately plotted points and trend lines
- Choose a suitable scale for any graphs.
- Uncertainties must be propagated in any calculations. Uncertainties on graphs usually requires the drawing of appropriate max/min best fit lines.